present subject. There is no doubt that the electric telegraph was a slow-growth invention, with a view to pecuniary and other advantage, being ever ready to lay hold of each scientific discovery and try to turn it to account. The question who first conceived the idea can never be satisfactorily answered.

After 1840 there is little to record of a purely electrical character bearing only on telegraphy, but there have been many very ingenious mechanical contrivances introduced for recording signals, for reproducing pictures and handwriting and for printing, for duplexing, quadruplexing and multiplexing telegraph lines, for increasing the rate of signaling and in many ways increasing the expedition with which messages can be sent. Of course, the success of many of these contrivances, and even their invention, depended upon an increased knowledge of the laws of electricity and magnetism. For example, effective duplexing, quadruplexing, etc., depends on a proper understanding of the electrostatic capacity of the line, and this was not understood properly until the mathematical investigations of Thomson and others cleared the matter. For the impetus towards discovery in this direction again we are largely indebted to telegraphy, for much of that class of work was suggested by the difficulties encountered in signalling through long submarine cables.

The invention of the telephone is fast becoming ancient history, and yet it will always mark one of the greatest of the useful applications of electricity. It does not call for more than a passing remark here, because electro-magnetically it is all in Faraday's and Henry's papers.

The radiophone should be mentioned because it marks the application of the discovery, by May and Smith, of the effect of light on the resistance of selenium. This effect has since been found in the case of a large number of other substances, but it is still an interesting field for research. A number of experiments on this subject have been associated with attempts to make things visible at a distance. No doubt it will ultimately be possible not only to talk to a distant party, but also to see the party talked to, and thus, as it were, look the party with whom you are conversing in the eye.

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(*To be concluded.*)

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*THE PROVINCE AND PROBLEMS OF PLANT PHYSIOLOGY.**

THE exploitation and survey of the flora of our continent is a task of such tremendous magnitude that it has consumed the greater portion of the energy of American botanists until within a few years of the present time. The constantly increasing number of workers attracted to the subject has made possible not only a more thorough organization of the interests of taxonomic botany, but has also permitted a great deal of attention to questions of general morphology and cytology. Within the last decade an awakening interest has been shown in subjects in the physiology of plants. This interest has been manifested by the introduction of physiological matter in the text-books on botany, by the organization of courses of instruction in this branch in some of the more prominent colleges and universities, and by the accomplishment of investigations of more or less importance.

Any subject is liable to misconception and misapprehension during the earlier stages of its introduction into any country, and plant-physiology in America is no exception to the probability.

A misapprehension of a subject is likely to be followed by a perversion of the facilities devoted to it, the neglect of its

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real and intrinsic phases, and finally, by the suppression of needed investigation in regions of the subject less fully developed. Furthermore, the distortion of the true nature of any branch of biological science is a misfortune which is bound to confuse thought and retard the progress of research. Misconceptions as to the true nature of a subject, on the part of workers engaged in it, are all the more dangerous since their expressions have the form and force of 'authority.'

A review of the courses of study, general addresses and recent publications dealing with the nature and limits of physiology, presented by American botanists is not at all reassuring. Many botanists harbor the preposterous opinion that the chief work in this subject has been accomplished in the thirty years in which active and continuous investigation within its limits have been in progress in the laboratories of the world. The persons in charge of botany in a number of institutions, in response to the demand for instruction in this branch, have labeled a course of section-cutting and reference reading 'plant-physiology,' and give the student no opportunity to acquire a knowledge of plants by actual experimental methods. If rarely he is afforded the opportunity to deal with the living plant under natural conditions it is to repeat some classic demonstration with a piece of stock apparatus to 'confirm' the results detailed in a textbook. The worst misapprehension of the subject is likely to occur in pure lecture courses based upon the text and reference books by 'readers' who have no part or interest in current investigations. Such courses are necessarily devoid of even the classic demonstrations, and the didactic character of the work quite naturally leads the student to the opinion that the subject is a closed one, and that the principles retailed him are not likely to be disturbed by future happenings.

That this state of affairs is by no mean imaginary is to be seen by the following quotation from a recent address by Dr. George Stone, in which he says: "One institution that I have in mind has advertised for years a thorough and complete equipment for work in vegetable physiology, and yet this same institution has scarcely had a single piece of purely physiological apparatus in its outfit in the whole time. The institution I refer to by no means stands alone in this matter."

The agricultural institutions have almost wholly neglected this subject of physiology, although "it is that branch of botany which has the closest relationship with all horticultural and agricultural knowledge and practice. In fact, it is the very foundation of these branches." "At the same time, we have been content to teach agricultural botany in our colleges for years, without considering it necessary to give the student any more than an elementary course in morphology, followed by flower analysis and the gathering of a herbarium, with a little histology thrown in."

The inattention to the physiological features of plant life is even more evident among experiment station workers, in the opinion of the author cited above: "There is no class of publications which shows such lack of physiological knowledge as from these, and it is shown by botanists, horticulturists and chemists as well. Their experiments frequently show that they know nothing about the functions of a plant or the factors which determine variation." The few exceptions to these statements are so well and widely known that they need no enumeration here.

In view of the above conditions, it is evident that any discussion which will bring the facts of the case into notice among American students will be of value.

Briefly stated, plant-physiology is concerned with the fundamental properties of

the protoplasm of plants, and the functions of the organisms into which it is formed. It is, therefore, a study of activities and regards structures from the standpoint of efficiency or functional value, and it includes the consideration of all reactions of growth, movement, metabolism, changes in form, irritability and other phenomena resulting from the activity of forces internal to the plant whether set in motion by internal or external stimuli. It merges into morphology in the subjects of growth and reproduction upon the one hand, and upon the other it underlies a portion of the domain of ecology, in the consideration of adaptative reactions, while with bacteriology and mycology it forms the basis of the study of pathology. Physiology and chemistry join in the consideration of the chemical activities and products of the organism, and the principles of physics are involved in the investigation of the plant machine.

It is not possible, nor would it be profitable, to separate the botanical branches too sharply in instruction or research. Some exposition of the principal functions of plants might well accompany an elementary course in morphology, and it goes without saying that a knowledge of anatomy is a prerequisite to the successful comprehension of the physiology of an organism, although some knowledge of the general principles may be obtained without it. Then again, it will often be found most profitable to extend work in physiology to include an interpretation of the more prominent adaptations, especially those of an ontogenetic character. To attempt to deal with such phases of plant life in instruction or research without a comprehension of the physiological principles involved is pure assumption.

In agricultural colleges and experiment stations the botanical problems and courses of foremost importance would be those dealing with nutrition and plant diseases. In this instance the work of the physiologist might well extend to cover almost all of the field of the pathologist.

The opinion that the main principles of physiology have been determined, and that only their minor and incidental application await delineation at the hands of the investigator, has been expressed concerning several subjects so many times in the last century that it needs no further notice at this time.

A systematic survey reveals the fact that, instead of a complete and thorough plotting of the great field of physiology, we have made here and there a few simple trails through the dense jungle of ungrouped and vaguely defined principles, and the greater part of the work is yet to be accomplished.

The fundamental problem of the constitution of living matter still confronts us. It is quite true that the chemical structure of its chief constituents, the proteids, is not yet determined, but even when this shall be known and the synthesis of this difficult group be accomplished we shall be but a step on the way, for there will still lie ahead of us the unknown physiological characters of the physical basis of life. Indeed, we may not say that we have determined even the limits of the gross anatomical existence of living matter, since there may well be stages of living matter or classes of organisms which so far have eluded our optical apparatus.

We have not yet succeeded in interpreting clearly even the cruder visible phenomena of the cell. The causes, character and purposes of cytoplasmic movement, the inter-relation of the organs of the cell, the nature of the activity of the plastids, the functional value of the nuclear constituents, and the operative relation of the protoplast to its membrane, are still open questions, while nothing but the crudest diagram of

the chemical activities of the cell is possible. The very apparent interprotoplastic threads have so far received no conclusive interpretation. Protoplasmic substance itself may wander from cell to cell, water, nutritive material, irritable or regulatory impulses may traverse these convenient pathways, but so far it has not been demonstrated that the structure in question is necessary for any of these functions.

The oldest branch of the subject is that of nutrition, and the beginnings of chemistry were made in researches upon the relation of the plant to the soil and air. The necessity and method of absorption of mineral salts and carbon dioxide is fairly understood, but the specific uses of the former and the manipulation of both classes of substances within the plant is unknown. Thus, for instance, the formation of food in the leaf from carbon dioxide and water is regarded as a photosynthesis, yet nothing is known of the process except that at an advanced stage a complex carbohydrate is produced. It is quite within the range of possibilities that the same products may result from a photosynthetic action on other carbon compounds. The composition of chlorophyll and its relation to the chloroplast are still in question. It may be lodged in interstices of the living matter or may form organic union with it. The chlorophyll may act as a converter of light into energy made available to the chloroplast, or its molecules may act as carriers in the synthesis. It is becoming even more open to doubt as to whether the activity of chlorophyll is exactly coincident with its absorption bands. Investigation in several lines must cooperate to solve this problem. The chemosynthetic activity of the nitrobacteria, and the thermosynthetic and electrosynthetic processes of other organisms, are hardly so well known.

The acquisition of nitrogen is a much vexed question, and the dawn of new investigations threatens to upset long cherished ideas as to the relation of the 'autophytes' to organic substances. The use, formation into crystals, resolution and transference of mineral substances in the plant body, is not satisfactorily explained. The balance and combined action of the several mineral elements in the soil is a matter of which we have no definite comprehension. Are the salts presented to the plant in commercial fertilizers absorbed as such and used as food, or are they subjected to synthetic activities, similar to those of the chlorophyll apparatus? Thus the presence of sodium salts in the soil is a benefit, amounting to a necessity in some instances, although this abundant element does not actually enter into the composition of protoplasm or plastic substance. The translocation, storage and formative selection of reserve material is bound up with that of fermentation, and the physiologist has progressed so far as to know that the preparation of reserve material, fluid and solid, for transportation is accomplished by means of ferments. He has isolated a few of these enzymes and has come to know that scores of others exist with action and chemical constitution unidentified. The vitalistic theory of fermentation will doubtless lurk among the residua of unexplained enzymic activities for many years to come. Indeed, the recent failure to extract a ferment from yeast gives the hypothesis a new lease of life. No doubt can exist, however, that the vital or regulatory action of the organism does play a part in these phenomena which we are not prepared to appreciate, and the secretory action concerned here and elsewhere in the plant has not received a fraction of the attention given such functions in animals.

The paucity of information of the physiologist concerning the alkaloids, glucosides, pigments and other compounds in the plant

is accented by the efforts made to explain the formation of these substances in a speculative manner upon ecological grounds.

So far as general metabolism is concerned it is to be said that the physiologist locates a substance here and there in the cell as a product of general processes, but he is incapable of more than ill-defined theories as to the course of chemical changes. It could scarcely be otherwise with the structure of the chief components of protoplasm unknown. The meager facts and abundant differences of opinion concerning the contents of resin ducts, laticiferous tissue and 'excreta' in general may well lead us to hesitate in declaring these subjects 'closed' and fixed.

The ascent of sap is a problem which has defied the combined efforts of the physicist and the physiologist for more than a century, and the results obtained by several of the most reliable investigators in the last decade have only annihilated previous hypothesis. In such manner capillarity, imbibition, the intermittent activity of protoplasm, the Jaminian chain, the lifting power of transpiration, variations in tension of enclosed gas-bubbles, and recently the tensile strength of a column of water, have each in turn held the place of importance only to give way to the inexorable logic of fact. It is generally admitted that the imbibition method proposed by Sachs is the only known method by which water *could* actually attain the summit of a tall tree, and that this method *would* furnish only a minute fraction of the amount necessary. On the other hand, it is well known that the current does not travel in the walls, but in the lumina and pits of the tracheal elements. We shall be compelled to return to the living elements and begin the investigation anew.

Time does not suffice to relate the detailed problems of growth yet unsolved, but it is becoming more and more evident that molecular features of growth are hardly at all determined, as well as the relation of this process to correlative and environmental forces.

The consideration of the effect of physiological factors, such as nutrition, light, etc., upon development and stature promises results of sweeping importance to all branches of biological science, if the few contributions which have appeared in this department may be taken as an index.

The nature of the irritability of plants, its development from the primitive reactions of protoplasm, the mechanism of reaction and transmission of stimular resultants, and the general irritable organization of the vegetal organism are yet hardly touched upon. In fact, so little understood is the sensitiveness of plants that biologists in general stand aghast at the daring of those investigators who seek to reduce it to terms comparable with those used in the description of animals.

As a specific case of incompleteness it may be mentioned that the path or conducting body for impulses in plants has not been determined in any single instance, nor has any cohesive theory as to a method of transmission ever been propounded. One may readily imagine the condition of animal-physiology if all information concerning the nervous system were wiped out of existence, and it would be known that the arm was moved by changes in form of lumps of tissue in that organ, which were set in motion when stimuli were applied to some distant organ with no apparent connection with the muscle.

The subject of reproduction has hitherto necessarily been considered from a purely morphological standpoint, although hundreds of titles of contributions upon the subject wrongly denote a physiological treatment. The time seems ripe for the physiologist to carry on researches upon the activities concerned, and some few splendid

contributions upon this phase of the subject are beginning to appear.

Lastly, it is the opinion of the writer that the physiologist has not yet entered upon the greatest task awaiting him, in the translation of the forms of activity shown by the vegetal organism into a system of general physiology, establishing a secure basis upon which coordination of accrued results may be made, a consequent better organization of the forces of attack upon waiting problems, and a more perfect articulation with all branches of biological science secured. The fact that this has not been accomplished is in part accountable for the nebulous ideas concerning the scope and status of the subject among even the botanical contingent.

In conclusion, it is to be said that it is manifestly impossible to do more than outline the developing principles which constitute the science of physiology, and suggest a few of the great gaps which remain to be filled by the efforts of future investigators. Moreover, the constant broadening of the biological sciences will demand a projection of physiological activity to cover widely diverging branches, and the interpretation of forms of activity of protoplasm yet unknown or but dimly recognized.

[Since the paper as above was prepared for the printer, Professor Loeb, in a discussion of the fundamental problems of animal physiology in this JOURNAL (Vol. VII., p. 154, 1898), has called attention to certain facts showing that the fundamental problems in the two branches are in part identical and in part closely parallel. His estimate of the outlook, "At no time since the period following the discovery of the law of conservation of energy has the outlook for physiology appeared brighter than at present,'' applies to this entire department of biological science.]

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THE MOUTH-PARTS OF THE RHYNGOTA.

Two papers on the above subject have been published within the last year or two, showing that there is yet a very considerable difference of opinion as to the real homologies of the beak and four inclosed lancets which form the Hemipterous mouth. The first of the papers in point of time and very much the most important is by Dr. Richard Heymons, in the *Ent. Nachr.*, XXII., 11, for 1896; the second is by Dr. N. Leon, *Zool. Anz.*, XX., 73, March, 1897.

Dr. Leon carefully describes the beak in several species of aquatic Hemiptera and particularly two little processes from the tip of the second (third) joint, which he homologizes with the labial palpi. It is to be noted that both Leon and Heymons assume it as unquestionable that the beak is a modified labium. In support of his thesis Dr. Leon shows that by proper manipulation the original paired character of the beak becomes evident and he makes the basal joint homologous with the submentum (labial cardines); the second with the mentum (labial stipes), and the third and fourth with the glossa and paraglossa. There is some confusion in the descriptions and in *Gerris* the third joint is made mentum without explanation. The chief point of the paper, however, is in the identification of the two little lateral processes from the so-called mentum as true labial palpi.

I have seen these same processes and would be inclined to consider Dr. Leon's arguments sound, if I did not believe the fundamental assumption that the beak is labial to be incorrect.

Dr. Heymons dismisses these processes from embryological data in the conclusion that 'labial palpi, consequently, are lacking in all *Rhyngota.* The processes discovered on the beak of *Nepa* and *Belostoma* are not really such, but must be regarded as a secondary process of the third joint of the beak.